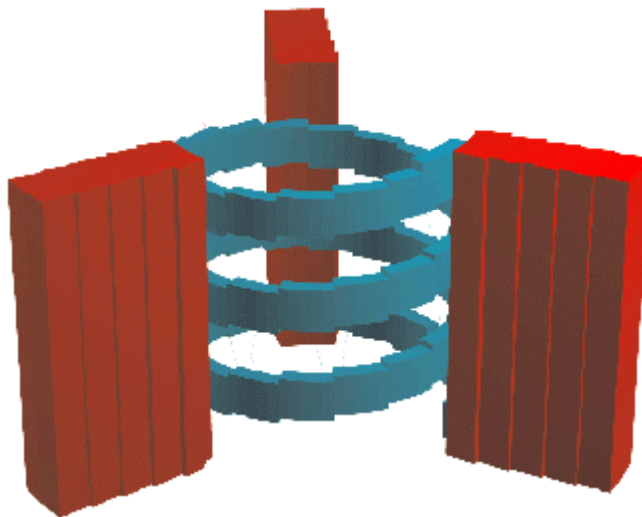


Computer Simulation of Microwave Devices

The accurate simulation of cold-test results including dispersion, on-axis beam interaction impedance, and attenuation of a helix traveling-wave tube (TWT) slow-wave circuit using the three-dimensional code MAFIA (Maxwell's Equations Solved by the Finite Integration Algorithm) was demonstrated for the first time (ref. 1). Obtaining these results is a critical step in the design of TWT's. A well-established procedure to acquire these parameters is to actually build and test a model or a scale model of the circuit. However, this procedure is time-consuming and expensive, and it limits freedom to examine new variations to the basic circuit. These limitations make the need for computational methods crucial since they can lower costs, reduce tube development time, and lessen limitations on novel designs.

Computer simulation has been used to accurately obtain cold-test parameters for several slow-wave circuits (refs. 2 and 3). Although the helix slow-wave circuit remains the mainstay of the TWT industry because of its exceptionally wide bandwidth, until recently it has been impossible to accurately analyze a helical TWT using its exact dimensions because of the complexity of its geometrical structure. A new computer modeling technique developed at the NASA Lewis Research Center overcomes these difficulties. The MAFIA three-dimensional mesh for a C-band helix slow-wave circuit is shown in the figure.



MAFIA three-dimensional mesh for a C-band traveling-wave tube helix slow-wave circuit.

This unprecedented approach was employed by using MAFIA to model a 32-GHz helical TWT for the Cassini mission in an attempt to explain an anomaly observed in the spectrum analysis of one of the flight model tubes. To investigate whether this anomaly was a result of the electron beam coupling to the backward wave oscillation mode, we used MAFIA

(for the first time) to accurately compute the dispersion relations for the fundamental amplification ($n = 0$) and backward oscillation ($n = -1$) modes of a helical TWT. Calculations of the gain at the point where the electron beam phase velocity line intersects the backward wave mode indicate that there is not enough interaction with the beam to produce spontaneous backward wave oscillation. Other computational efforts indicated that a strong second harmonic current exists only at the radiofrequency drive levels where the anomaly is observed. Since the effect is not observed within the range of parameters planned for use on the Cassini mission, even in the worst case analysis, this anomaly is not expected to appear. The 32-GHz TWT flight and engineering models for the Cassini mission have been packaged for flight, so it would have been virtually impossible to experiment with them to investigate the parameters of the anomaly. Thus, computer modeling was crucial to the explanation of the anomaly and to predicting the changes that could be expected during the course of the Cassini mission.

Simulation of microwave tubes is becoming even more essential because of the substantial opportunity for growth in the commercial demand for TWT's. In particular, two types of systems are of interest: satellite communications and local multipoint distribution systems (LMDS)--a concept that would cover major metropolitan areas with a grid of cellular stations operating at the Ka band, transmitting programming in competition with cable television systems. U.S. industry is proposing to invest more than \$35 billion in commercial Ka-band satellite communications systems over the next 6 years, requiring more than 5000 Ka-Band TWT's. One estimate suggests that 5000 to 6000 highly linear Ka-Band TWT's would be required to implement LMDS in the continental United States (ref. 4). Because cost and reliability are paramount for TWT's, computer simulation becomes indispensable.

References

1. Kory, C.L.: Three-Dimensional Simulation of Helix Traveling-Wave Tube Cold-Test Characteristics Using MAFIA. IEEE Trans. Electron Devices, vol. 43, no. 8, Aug. 1996, pp. 1317-1319.
2. Kory, C.L.; and Wilson, J.D.: Three-Dimensional Simulation of Traveling-Wave Tube Cold-Test Characteristics Using MAFIA. NASA TP-3513, 1995.
3. Kory, C.L.; and Wilson, J.D.: Novel High-Gain, Improved-Bandwidth, Finned-Ladder V-Band Traveling-Wave Tube Slow-Wave Circuit Design. IEEE Trans. on Electron Devices, vol. 42, no. 9, Sept. 1995, pp. 1686-1692.
4. Dayton, J.A., Jr. and Stevens, G.H.: Commercial Opportunities for Microwave Tubes. 1996 Crane Microwave Tube Conference, Nov. 13-14, Bloomington, IN, 1996.

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